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ELECTRONICS IN SURVEYING

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ELECTRONICS IN SURVEYING

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The following expression is quoted from the Report of the Fourth Texas Surveyor's Short Course Conference:

"It is said that the early Spanish surveyors engaged to survey the portions and other tracts in South Texas, used a simplified form of surveying with more ease than accuracy and with great appeal to a lazy man under a south Texas sun.

"He backed his pony up to the beginning point and headed him in the general direction of north, jabbed his espuelas into the sides of his caballo, thereby inducing a steady trot and every time the pony's right front foot hit the ground, the surveyor called it a vara and for every hundred such events, the surveyor tied a knot in the rawhide string he carried. Without too much effort he had made a survey that a lot of surveyors would fuss over for a day or two."

Now I do not wish to imply that I advocate this method of surveying. I merely use it to illustrate one of the early uses of time for measuring distance. Over 30 years ago, I sketched several hundred miles of Cuban roads for military purposes, obtaining my distances by using a stop watch to time my horse's stride, having previously calibrated my horse's walk, trot, and gallop over a measured course.

To go to a ridiculous extreme, it is said that distances were frequently described in the early days of Texas by the distance covered on a horse while the rider smoked a certain type of cigar.

Since clipper ship days we have heard the expression, "eight days out of Boston," or "five days from Portsmouth." Even now an airplane pilot often speaks of a certain flight as 4 1/2 hours instead of, let us say, 810 miles, if he figures his average speed will be about 180 miles per hour.

However, until the last decade, few believed that accurate surveys would ever be made where speed and time would be used to measure the distances. Yet within that short period of time, electronic surveying has emerged as a reality and as aid and even competitor to the established surveying techniques. In surveying by electronic methods, we use the fastest thing that exists, the speed of light or of radio waves.

Now to use round figures, light or radio waves travel at the amazing velocity of 186,000 miles in a single second. Therefore our clock must be accurate to 1/186,000 of a second to measure any distance to the nearest even mile. Actually we are measuring distances up to 500 miles and we are reading our distances up to the nearest half foot. This would appear to mean a timing accuracy of about 1/1,860,000,000th of a second. Now I don't mean to imply that we are actually obtaining that accuracy, but we are measuring distances of hundreds of miles with an accuracy of about 10 feet, which means that our average timing accuracy is somewhere in the region of 1/100,000,000 of a second. Unfortunately, if I were to try to describe in detail, even one of these timing methods, I would use the most of my allotted

time. It suffices to say that by combining the principles by means of which your electric clock runs, and keeps time with the use of the oscilloscope which actually allows us to "see" extremely small time intervals, this timing accuracy becomes possible.

Now the use of time to measure distance has one very great advantage. If we know the true value of the speed of radio waves, and if our system of correction for meteorological changes and the earth's curvature are accurate, there is no greater error in a 500 mile distance than there is in a 50 mile distance. When you use a yardstick or a steel tape to measure a long distance, any error in the tape or yardstick is multiplied by distance and can become very great for a long distance. With the electronic methods, the average error of, let us say 10 feet, will be the same at any distance, and while the proportional error is 1/25,000 at 50 miles it is 1/250,000 at 500 miles.

Now maybe I have made all this seem too simple. Actually, years of research were required to obtain this accuracy. For instance light and radio waves travel at the constant speed only in a vacuum. However our measurements are not made in a vacuum, but in air, which slows them down. As the air becomes more dense and more moist they are slowed still more. Therefore it was necessary to do research to find out exactly how much the velocity changed with different conditions of temperature and humidity from its value in a vacuum. We cannot run our clock at a variable rate to account for these changes, so we run our clock at some constant average rate and make corrections for the changes. We measure the temperature and humidity of the air and use the formulas developed by experimentation to obtain our corrections.

Fortunately, for a rather wide band of wave lengths the effect is the same regardless of the wave length. This is true for waves which are only a fraction of an inch in length up to waves of hundreds of feet in length. However, when we start using light, with its very short wave lengths, we find that these velocity changes in air are also different for different wave lengths. The longer "red" light waves have faster speeds in air than the shorter "violet" waves so we have a "color correction." That makes the problem sound very difficult but again it has been solved by adopting correction systems in the case of those instruments which use light instead of the non-visible radio waves.

There are actually about three different wave bands now in use, one is light itself, the second is a high frequency band whose wave lengths vary from about 1/2 inch to about 100 feet, and the third is a band lying just above the broadcast band where the waves are over a mile and a half long. Now the instruments in the latter band have certain great advantages, but also disadvantages. Since the first two travel through the air in almost a straight line, it is necessary to be able to "see" between the points over which the distances are being measured. This cuts down the measured lengths to "line of sight." But the long waves of the third group have the property of spreading out or diffusing and thus bending closely around the earth for great distances. Thus, these waves can be received for hundreds of miles, far beyond the line of sight. Thus, the amount of power is the important factor in obtaining long range. However, these long waves which follow the curvature of the earth are also slowed down in different amounts by the kind of terrain over which they are passing, in much the same manner that a stream of water flows more slowly over porous sand which absorbs part of the water, than it does over rock or hard clay. For instance, they travel faster over a good conducting surface like sea water than they do over dry sand or rocky

terrain. Naturally these effects are very hard to assess so we can obtain much greater accuracy with the "line of sight" wave lengths.

Now let us look at some of the various instruments using these principles. First we will consider some of the short range instruments. One of them is the Bergstrand geodimeter made in Sweden.

Short Range Instruments

To look at the geodimeter, one would never guess that it was designed as a surveying instrument.

Figure 1.

This instrument is capable of measurements of very great accuracy according to repeated tests in Sweden. Very red light, almost approacing invisible light, is reflected from a plane mirror target which is located at distances between 6 and 10 miles away. A proportional accuracy of 1 part in 300,000 is claimed or only about two inches in distances up to 10 miles. With an accuracy of this order it is possible to measure and compute in a matter of hours, a base for triangulation which would require five to ten days to measure by our conventional methods.

Figure 2.

Another electro-optical instrument developed under the auspices of the U. S. Engineers Research and Development Board, is shown in Figure 2. Again light is used and is reflected from a corner cube mirror target at distances up to several miles. The accuracy of this instrument is not high, being about 1 part in 2000. However, it serves a very useful purpose in topographic surveys, for in addition to measuring distance, it will also measure angles with topographic accuracy. The angle measuring accuracy is said to be about 1 minute of arc.

Figures 3 and 4.

Another instrument in the topographic class is Moran which reads distance directly on dials. Moran uses high frequency radio waves. It is small and compact as shown in Figure 3 and 4. The target is a dipole antenna. In the Moran instrument the waves are not reflected but are rebroadcast. There is a fixed delay in the receiver at the target between the time the signal is received and the time it is re-broadcast, but this delay is measured and compensated for at the time the distance is read. The Moran instrument can be carried around in a truck or boat and at any desired point the distance to the targets can be read. The accuracy is of the order of ± 25 feet for ranges up to about 15 miles.

Long Range Instruments

Many long range instruments have been developed and are in use at present. These are generally of two classes: a) those using long waves, and b) those using short waves. As examples of the former we have Loran, Decca, Lorac, Raydist, and the Electronic Position Indicator or E. P. I. The latter instrument is a development of the U. S. Coast and Geodetic Survey. Extensive use

is made of these long range instruments in hydrographic surveying where the lesser accuracy of the long waves can be tolerated. They are very convenient for positioning a ship or boat while soundings of the ocean bottoms are being made and they enable us to chart ocean bottoms with great facility.

Figure 5. E. P. I.
Figure 6. Raydist

These instruments are very useful for hydrographic surveys inasmuch as some of them are capable of measuring distances of hundreds of miles with an accuracy of 100 yards.

Intermediate Range Instruments

Now in between the two classes of instruments just described, we have the intermediate range instruments. Instruments of that class use wave lengths of about 1 cm to 1 meter. These are "line of sight" waves in the radio band the path must clear between target and instrument. However, we can place these instruments in an airplane and fly high enough to measure very great distances.

Figure 7

In figure 7 we see an example of the manner in which shoran, one of the instruments of this class, can be used to measure long distances. As an airplane containing one, flies "across the line" between two targets, it continually measures two distances to each target or "ground Station." Obviously we can add these pairs of distances and when the sum distance is the smallest the airplane is directly over the line joining the two stations. To reduce this "sum Distance" to the "map" or geodetic distance is merely a mathematical process involving the altitudes of the airplane and the ground stations and measurements of the meteorological elements.

In this system we run into a further difficulty. As the radio waves leave the airplane and go to the ground station, they are gradually slowed down by the denser and moister atmosphere nearer the ground. Nevertheless, we can measure these changes in density and humidity and make very accurate corrections for these velocity changes.

As examples of this type of instrument, we have the British Oboe and the American shoran. Both were developed originally as blind bombing instruments. Shoran is now being used extensively for surveying by the United States, Canada, and Australia.

Figure 8.

In Figure 8 we see the largest electronic surveying project ever attempted. The only possible way of making this survey is by electronic methods. This survey is being made for the purpose of accurately locating tracking stations for guided missile research, but as frequently happens in wartime research, we find an important peacetime application. As a result of this survey we are correcting our maps of this entire area and errors of many miles have been discovered.

Photogrammetric Mapping

Thus far the topographic, hydrographic, and geodetic control survey applications have been stressed. However we have a direct application to mapping which will enable us to rapidly map difficult terrain. Once we have measured distances between these stations and used those distances to compute their position on the earth's surface, we can locate a photographic airplane in the air at the same time it is photographing the ground.

Figure 9.

Figure 9 shows how this is done. Already the Canadians have made extensive use of shoran photographic mapping in Canada. Certainly the vast underdeveloped areas of the world will be mapped far sooner by these new methods than they would have been by the slow conventional surveying techniques.

I do not wish to give the impression that these electronic methods will ever completely replace conventional methods, but they will certainly supplement them. Actually, the demand for conventional surveys will increase following the rapid production of maps by the long range techniques, for the local surveyor will require closely spaced monumented points. Yet, even in those detailed surveys, such instruments as the geodimeter, Moran, and others will be used in conjunction with the transit and plane table.

The Velocity of Radio Waves

Thus far it has been assumed that we know the basic velocity of radio waves in a vacuum. Actually we are still somewhat uncertain of this figure. At the present time most physicists agree that we have been using a value about 8 miles a second too low. Within the last few years, many observers have made accurate observations which have ranged from 186,280 to 186,283 miles per second. Strange to say, several of those measurements have been made by instruments designed for surveying. When first tested, using the generally accepted value of the velocity of light, errors with distance occured which could only be attributed to the use of too low a velocity. Earlier in this paper, I stated that when time is used to measure distance, the error does not increase with distance provided we know the value of certain physical constants, one of which is the velocity of radio waves. Here we have an example of the surveyor actually helping to determine these constants by a trial and error method. Figuratively we may say that he is lifting himself up by his bootstraps.

In this brief paper, I have attempted to highlight the developments that have taken place in electronic surveying. Before concluding, it may be of interest to know what stimulated this rapid development. Actually, as is so frequently the case, electronic surveying was a by-product of war. The demand for an instrument which would enable a bomber to locate its target even when obscured by clouds or darkness, was responsible for the preliminary development of shoran, Oboe, and similar devices. Surveyors had long dreamed of utilizing radio waves in this manner but the cost of development was too great. The geodetic engineer and the photogrammetrist immediately seized upon these tools of war and by design modifications and skillful techniques, secured accuracies far greater than the original design accuracy. In fact, shoran is now being used with astounding accuracy for bombing in Korea

and its improved quality is a direct result of the studies of the geodetic engineer. Had the geodesist been able to secure funds for his electronic distance measuring research decades ago, all of his studies would have been of untold value to the military.

One further use of our electronic surveying methods should be mentioned in closing. Thus far only horizontal distance measurements have been discussed. Yet to complete a map we required elevation data as well. And we are already using instruments which "bounce" radio waves from the surface and thus measure the difference in height between an airplane and the ground. In fact some instruments have been designed which actually draw a profile of the ground beneath the airplane.

Conclusion

Our research has only begun, yet tremendous strides have been made despite great handicaps. Thus far, many of our instruments have not been designed for surveying but are modified wartime instruments. Much of the research has been accomplished with military personnel. That means a constant turnover of technicians. Continued progress is inevitable and so we see another example of the impact of electronics on our civilization. We can fire "electronic bullets," count them as we fire them, and measure distance in that manner. History has proved that development follows good maps. Who can predict what the impact of these new techniques will be during the coming century?

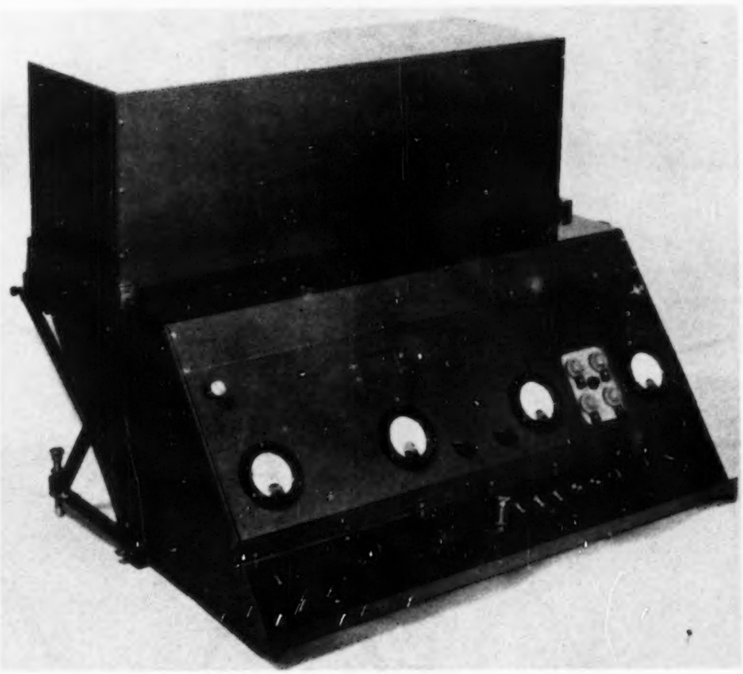

Fig. 1 — AGA Geodimeter, Front View

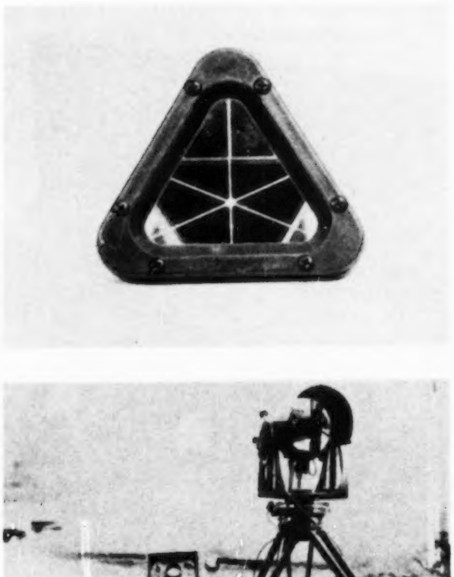

Fig. 2 — Electro-Optical System

Fig. 3 — Moran Instrument in Truck

Fig. 4 — Moran Target

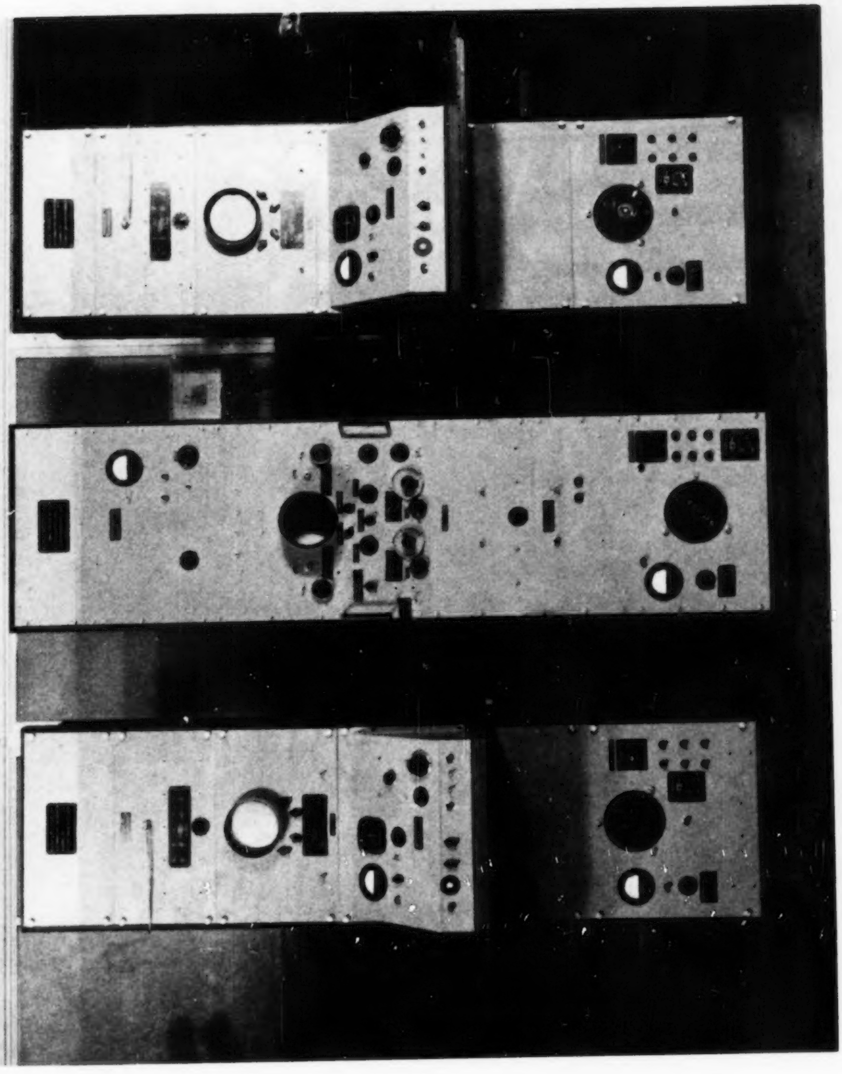

Fig. 5 — E. P. I.

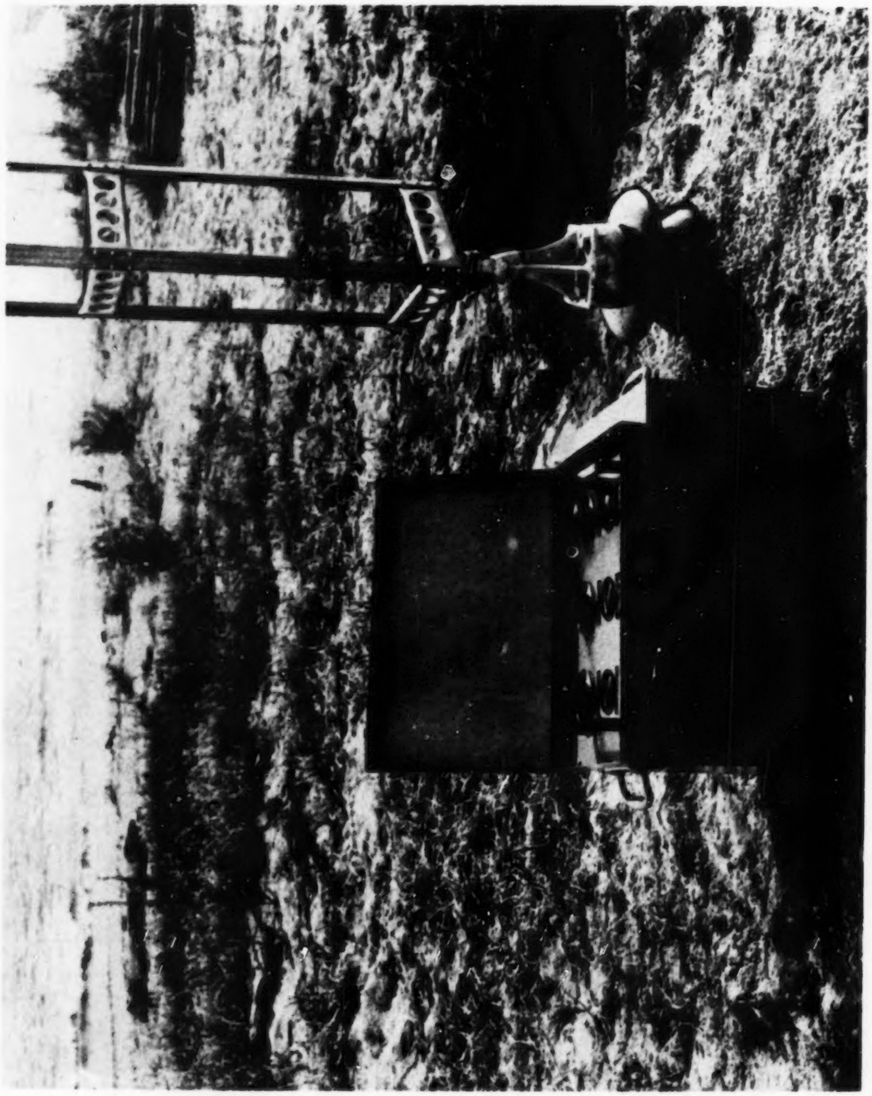

Fig. 6 — Raydist

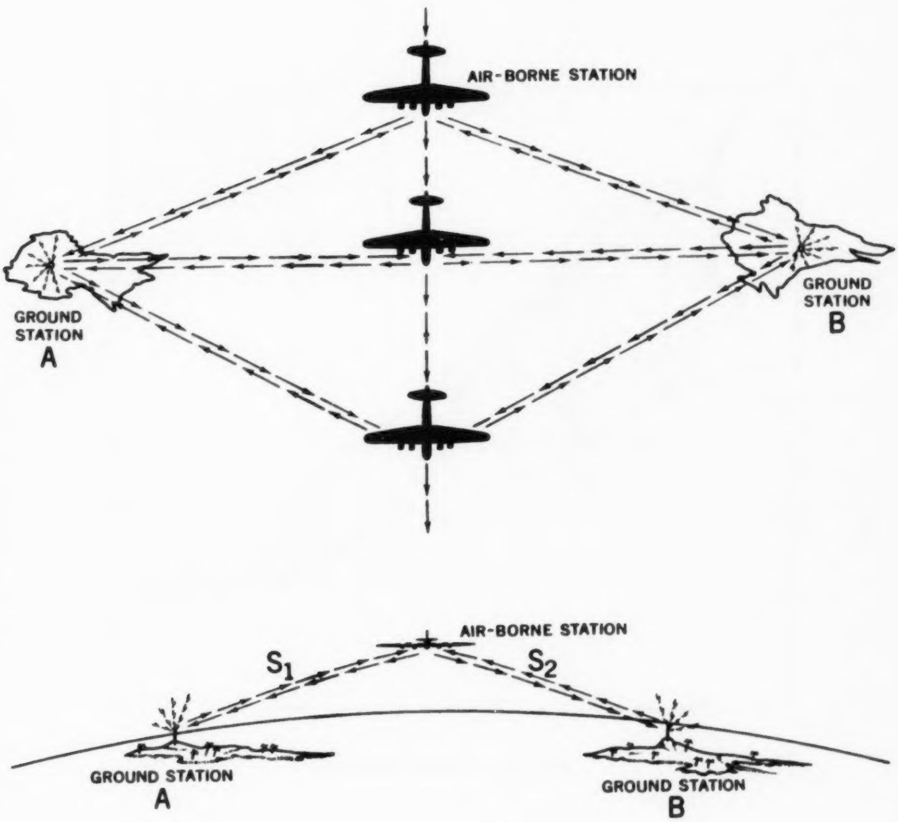

Fig. 7 – Shoran Line Crossing

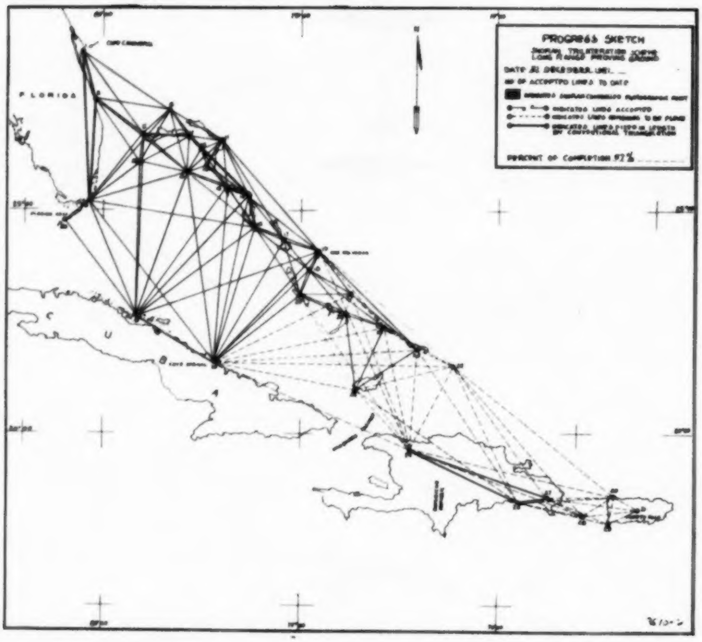

Fig. 8 — Shoran Scheme

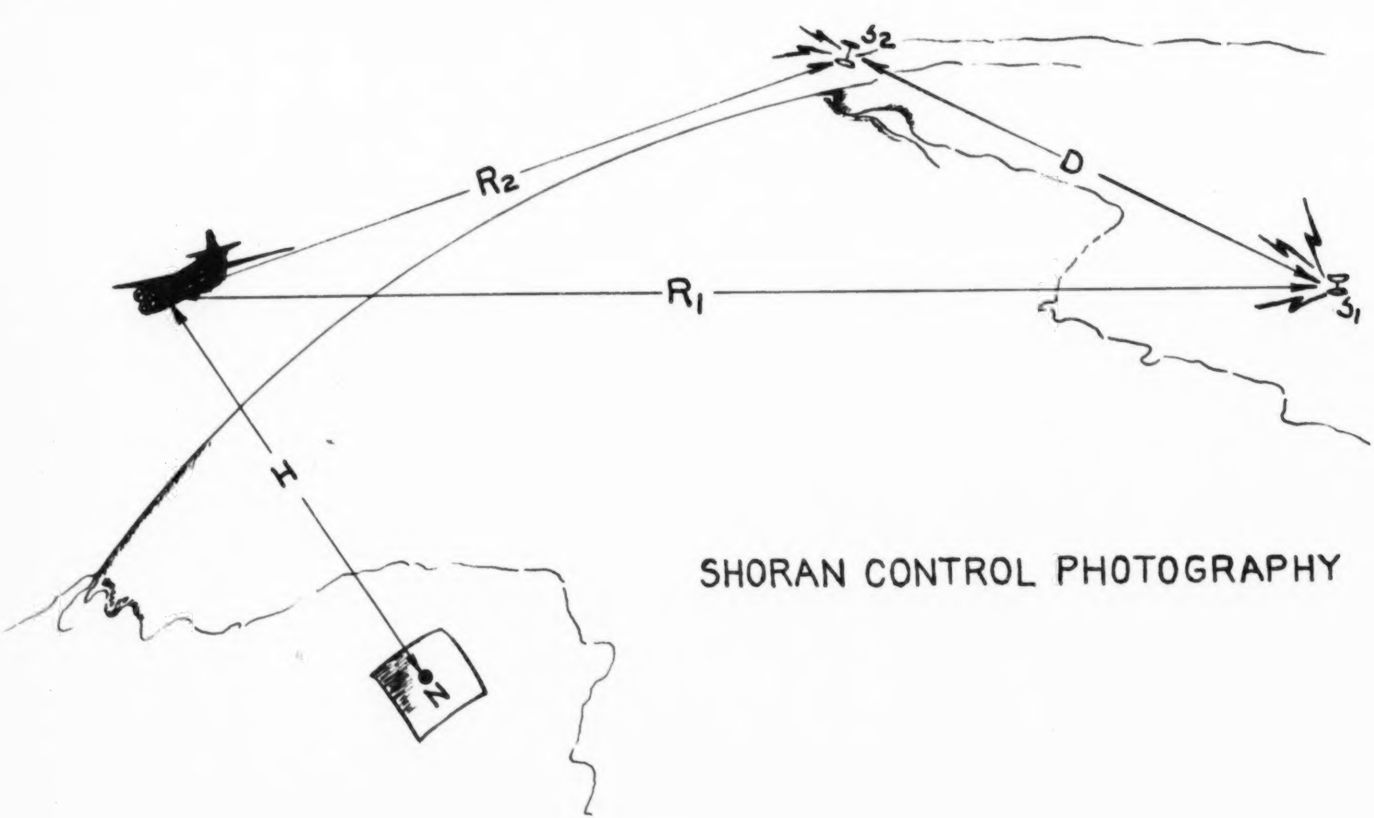

Fig. 9

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